

THEORETICAL AND EXPERIMENTAL STUDIES OF STABILIZED
METASTABLE HELIUM(V) JET PROPULSION LAB PASADENA CA
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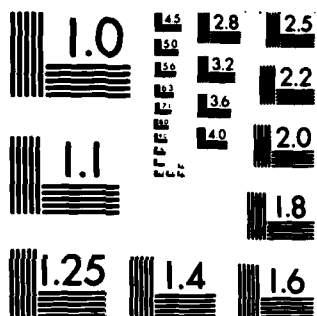
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Numerical calculations have shown that the atomic phase of He IV (bulk spin-polarized triplet helium) should have a face-centered cubic crystal structure. A new, metallic phase of He IV has been discovered and shown to have lower energy than the atomic phase. A fundamental model of metallic He IV has been formulated which includes electron spin-spin and spin-orbit interactions as well as the coupling to the radiation field. The problem of metastability of metallic He IV has been formulated mathematically and will be used for future numerical calculations. A physical mechanism has been identified which might be instrumental in stabilizing metallic He IV. <i>Originator Supplied Keywords Included</i>	

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RESEARCH OBJECTIVES

The principal objectives of the multiphased research program on stabilized metastable helium are to:

- (a) Develop an understanding of the physics of He IV, the bulk metastable triplet helium.
- (b) Produce He IV in the laboratory and investigate its physical properties.
- (c) Devise methods for stabilizing He IV for long periods of time, of the order of several years.
- (d) Develop methods for usefully extracting stored energy from He IV.

The objectives for the second phase of the research program, covered by this report, were to:

- (a) Complete numerical calculations based on the phenomenological model of He IV-A investigated during Phase 1 of the program.
- (b) Include effects of electron spin-spin and spin-orbit interactions into the theory of He IV-A previously developed.
- (c) Attempt to produce microcrystals of He IV-M in superfluid helium with existing equipment at JPL and detect them by light scattering.

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Chief, Technical Information Division

STATUS OF RESEARCH

Numerical calculations to determine the ground-state energy and the crystal structure of He IV-A [1], the atomic phase of bulk He*, have been completed and the results are being published [2]. The calculations indicate that face-centered cubic is the preferred crystal structure of He IV-A.

A major theoretical achievement during the reporting period was the discovery, on the basis of theoretical analyses and numerical calculations, that the metallic phase of He IV is of lower energy than the atomic phase (He IV-A). This makes metallic He IV the preferred phase to be looked for experimentally. Metallic He IV is predicted to have almost the same density as water and should be thermodynamically stable at zero external pressure. The electronic stability is of course an open issue. The work on He IV (including the metallic phase) has been submitted for publication in the Physical Review B1 [3].

As a result of the said discovery, the research effort has been refocused toward elucidating physical properties of metallic He IV and, most importantly, the question of its metastability. In addressing these problems, the following progress has been made during the reporting period:

- (a) A fundamental model of metallic He IV has been formulated which includes electron spin-spin and spin-orbit interactions as well as coupling to the radiation field.
- (b) An effective Hamiltonian for metallic He IV has been derived which includes the above effects and is valid through fourth order in the fine structure constant.
- (c) The problem of calculating the electronic energy band structure of metallic He IV has been formulated and a computer program written and partially tested (Prof. S. E. Trullinger, USC).
- (d) An approach to address the metastability question of metallic He IV has been formulated mathematically.
- (e) A collective effect in metallic He IV has been identified which has the promise of providing an energy barrier necessary to make metallic He IV metastable.

The first report on this work will be in a paper now being readied for publication [4].

PUBLICATIONS

A paper by Jonas S. Zmuidzinas entitled "Spin-Polarized Triplet Helium" has been submitted to the Physical Review, Part B. A revised version of the paper, in response to a referee's report, will be submitted soon.

A paper by Jonas S. Zmuidzinas entitled "Metastability of Metallic He IV" is being readied for publication in the Physical Review, Part B.

A paper by Myron L. Tapper entitled "Ground-State Energy Calculations of He IV-A" has been accepted for publication in the Journal of Physics C: Solid-State Physics, subject to minor modifications.

A paper by Jonas S. Zmuidzinas entitled "Collective Fields in Fermi Systems" is being readied for publication in the Physical Review, Part B.

A paper by J. L. Watkins, J. S. Zmuidzinas, and G. A. Williams entitled "Helium Molecules on the Liquid Helium Surface" was published in the Proceedings of the 17th International Conference on Low Temperature Physics, Karlsruhe, 15-22 August 1984, p. 1197 (Elsevier Science Publishers, 1984).

PERSONNEL

During the reporting period the following personnel were involved in the research effort:

Dr. Jonas S. Zmuidzinas, Principal Investigator, Earth and Space Sciences Division, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California 91109.

Dr. John L. Watkins, Earth and Space Sciences Division, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California 91109.

Dr. Myron L. Tapper, Rockwell International Corporation, Shuttle Orbiter Division, 12214 Lakewood Boulevard, Downey, California 90341. The services of Dr. Tapper, at a level of approximately 24 hours per week for the reporting period, were acquired by JPL through a subcontract to Rockwell.

Professor S. E. Trullinger, Department of Physics, University of Southern California, Los Angeles, California 90007. The consulting services of Professor Trullinger were acquired by JPL for a period of approximately two months during the summer of 1984.

INTERACTIONS

Jonas S. Zmuidzinas gave the following presentations during the reporting period:

17-18 July 1984, NASA Ames Research Center (Moffett Field, CA), invited talk "Metastable Helium" at the Aeronautics 2000+ Revolutionary Concepts Meeting;

19 July 1984, Aerojet TechSystems (Sacramento, CA), seminar: Stabilized Metastable Helium;

14 September 1984, Rockwell Science Center (Thousand Oaks, CA), seminar: Stabilized Metastable Helium;

24-25 September 1984, California Institute of Technology (Pasadena, CA), three talks on He IV at Metastable Helium Workshop.

During the period 22-25 August 1984 John L. Watkins attended the 17th International Conference on Low Temperature Physics, Karlsruhe, FRG, and presented a joint paper (with J. S. Zmuidzinas and G. A. Williams) entitled "Helium Molecules on the Liquid Helium Surface."

On 24 July 1984 Dr. D. Jassowski and Dr. S. D. Rosenberg of AerojetTech Systems (Sacramento, CA) visited JPL to discuss the metastable helium effort.

Jonas S. Zmuidzinas hosted an AFOSR/AFRPL/JPL Meeting on Metastable Helium at JPL on 19 June 1984.

REFERENCES

- [1] J. S. Zmuidzinas, JPL Technical Memorandum 33-653 (1973).
- [2] M. L. Tapper, "Ground-State Energy Calculations of He IV-A," to be published in the Journal of Physics C: Solid-state Physics.
- [3] J. S. Zmuidzinas, "Spin-Polarized Triplet Helium," submitted for publication in the Physical Review, Part B.
- [4] J. S. Zmuidzinas, "Metastability of Metallic He IV," to be submitted to the Physical Review, Part B.

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